CHAPTER 8: STEAM INSTALLATION BEST PRACTICES

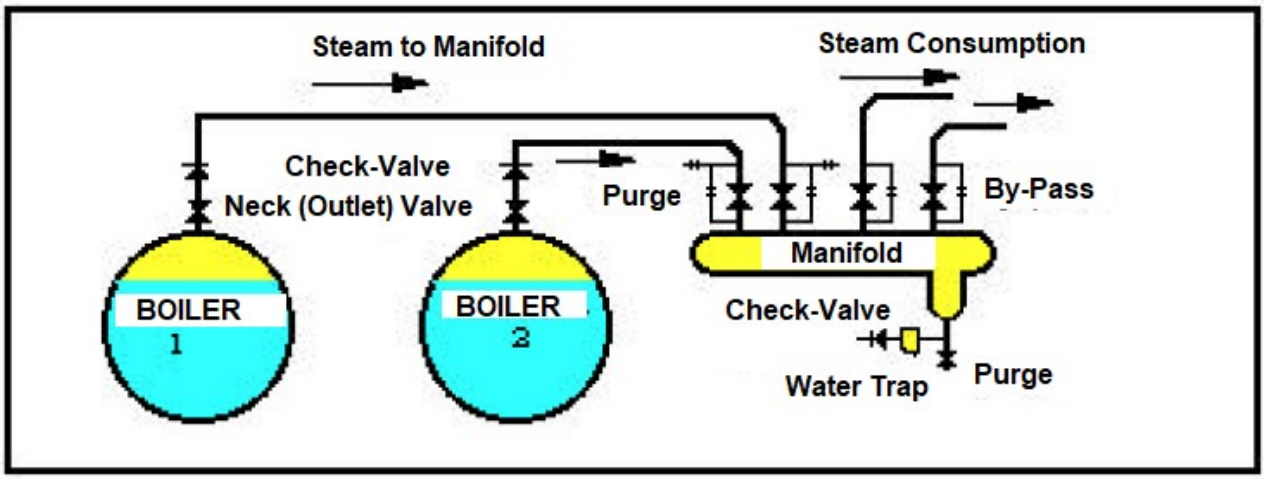
The "neck" valves (or steam outlet valves of boilers), when boilers are connected to steam distributors ("manifolds"), which may have valves upon connection to the distributor manifold due to other operating boilers, must have a small purge valve to keep the pipe empty of water.

If both valves are closed and the pipe is full of water for some reason (due to a leak in the valves), this water, upon heating, can expand and create a hydraulic pressure of such magnitude that it can cause the neck valve or the manifold valve to burst.

All large manifold valves must also have a small bypass valve—that is, in parallel—which will open first and close last, heating or draining to avoid thermal stress that could damage the larger valve.

When several boilers are connected in parallel (i.e., to the same manifold), it is advisable for **each boiler to have a check valve**. This allows each boiler to maintain its internal pressure, especially if the pressure drops.

Furthermore, if there is a leak or rupture in the pressure vessel, the problem will not be aggravated by steam entering from the other connected boilers.



Steam is carried through pipes to the locations where it will be used.

The pipe's dimensions or capacity to carry a specific quantity of steam, defined as kilograms of steam per hour, are determined for each steam pressure and quality (saturated or superheated at a given temperature).

This capacity is limited by the maximum steam velocity inside the pipe, which depends on the type of steam, the service provided, the pressure drop (pressure loss), and even the tolerable noise level of this flow.

To prevent damage to pipes and fittings, **the steam must be dry (without water droplets**, which will form as the steam cools due to heat loss from the pipes if it is saturated).

These droplets are like pellets or shot that travel at high speed and collide with metals or other materials, causing erosion or scratching, similar to mechanical corrosion.

Therefore, **the pipes must be insulated to prevent heat loss and steam condensation** (it is even advisable to insulate the pipe supports, using brackets that can be fully or partially insulated to avoid thermal bridges).

Flanges, plates, and valves must also be insulated, as their large exposed surface area causes significant heat loss. Removable insulating blankets can be installed on these surfaces for repairs. Additionally, the system must be dried (water removed) using water separators with steam traps.

The pipes must always slope in the same direction as the steam flow, in order to prevent the formation of water "pockets," which, if carried along by the high speed of the steam, instead of being "balls," will be a "cannonball" or **"water hammer" that will cause enormous damage when it hits the same pipe at the end of the line or a piece of equipment. Causing serious accidents in some cases.**

The most important benefit of insulation, over time, is fuel savings, which can amount to a very high value per year of losses.

For example: an uninsulated 3-inch pipe, 1 meter long, carrying steam at 10 kg/cm² (142 PSI), in an environment with an average temperature of 20°C (68°F), exposed in a place without wind or forced air, can produce an annual heat loss equivalent to more than 500 liters of fuel oil (this heat loss increases if there are winds or drafts).

The lack of thermal insulation on steam distribution pipes effectively reduces the boiler's capacity and thus its efficiency.

Let's look at a table of losses due to lack of insulation, on a flat surface, of dark iron (emissivity E= 1), in an environment at 21ºC, without "wind" (without air currents).

Hot iron Surface Temperature in °C	Temperature difference Difference °C (between iron and ambient)	Heat loss Kcal/m²/h
38	17	135
93	72	799
149	128	1772
204	183	3103
260	239	4895
316	295	7227

A similar table could be established for bare pipes, whose loss per linear meter will depend on the diameter and internal temperature of the fluid it transports, which, for example, if we consider the previous conditions, we would have:

Caño nominal	**Dif. temperatura ºC**	**Pérdida Kcal/m/h**
Caño 1/2"	93ºC	61,9 "
"	149ºC	136 "
Caño 3/4"`	93ºC	76 "
"	149ºC	169 "
Caño 1"	93ºC	93 "
"	149ºC	206 "
Caño 2"	93ºC	161 "
"	149ºC	356 "
Caño 3"	93ºC	231 "
"	149ºC	511 "

As shown in the tables above, insulation is crucial to prevent heat loss and condensation of saturated steam.

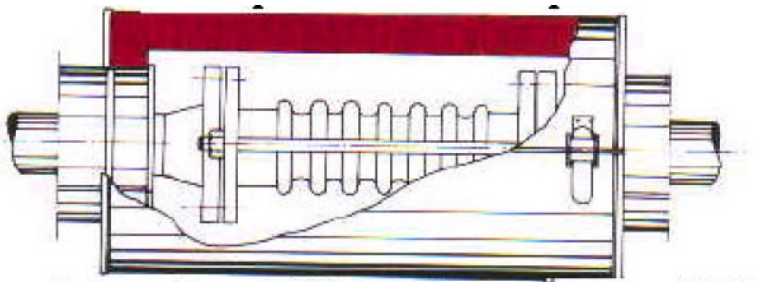
In the last reading for the 3" pipe, if we consider the temperature difference of 149°C, where the internal steam density is approximately 8 kg/cm², we see that we are condensing almost 1 kg of steam per hour per linear meter of uninsulated pipe. This is assuming an external temperature of 21°C and no drafts (drafts would increase the loss).

This is a very significant loss and a condensed inconvenience that causes all sorts of problems: it interferes with regulation and causes erosion of the regulating valve seats, it causes water hammer if not properly extracted, it reduces the pipe's cross-section if it doesn't have the correct slope, it causes corrosion by dissolving acidic gases, and it affects the transfer.

The fact that a pipe is "perfectly" insulated does not mean it won't lose heat, but rather that it will lose less heat. Valves, joints, and flanges without insulation cause significant heat losses, which increase as the operating temperature (i.e., steam pressure) rises, and depending on the location where it is installed (protected from wind, rain, etc.).

The insulation of these fittings must be designed so that they are easily removable, and that if steam or water leaks occur, they must be channeled to the outside, not only for immediate repair.

but also because if these leaks occur within the insulation, it ceases to insulate and, moreover, areas of severe corrosion are caused by the presence of moisture and oxygen.



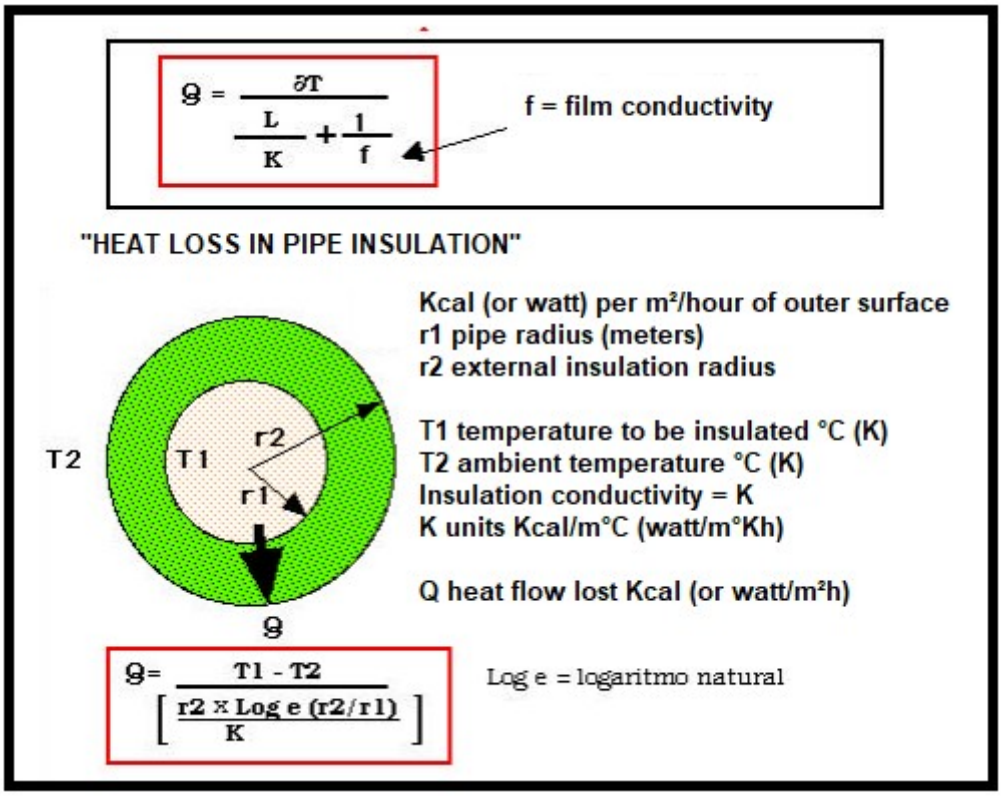
The losses through expansion joints are significant.
Always allow for proper expansion/contraction of the joint.

We must remember that insulating materials are limited to those that do not cause harm to people (such as asbestos, which can cause serious problems if inhaled, its use is prohibited).

The heat loss from a valve is equivalent to 1 meter of uninsulated pipe or 10 meters of insulated pipe of the same diameter.

The heat loss from a plate is equivalent to 0.3 meters of uninsulated pipe or 3 meters of insulated pipe of the same diameter.

Piping insulation heat loss is proportional to the temperature difference.


$Q = \frac{\partial T}{\frac{L}{K} + \frac{1}{f}}$
f = film conductivity
"HEAT LOSS IN PIPE INSULATION"
Kcal (or watt) per m²/hour of outer surface
r1 pipe radius (meters)
r2 external insulation radius
T1 temperature to be insulated °C (K)
T2 ambient temperature °C (K)
Insulation conductivity = K
K units Kcal/m°C (watt/m°Kh)
Q heat flow lost Kcal (or watt/m²h)
T2
T1
r2
r1
Q
$Q = \frac{T1 - T2}{\left[\frac{r2 \times Log\ e\ (r2/r1)}{K}\right]}$
Log e = logaritmo natural

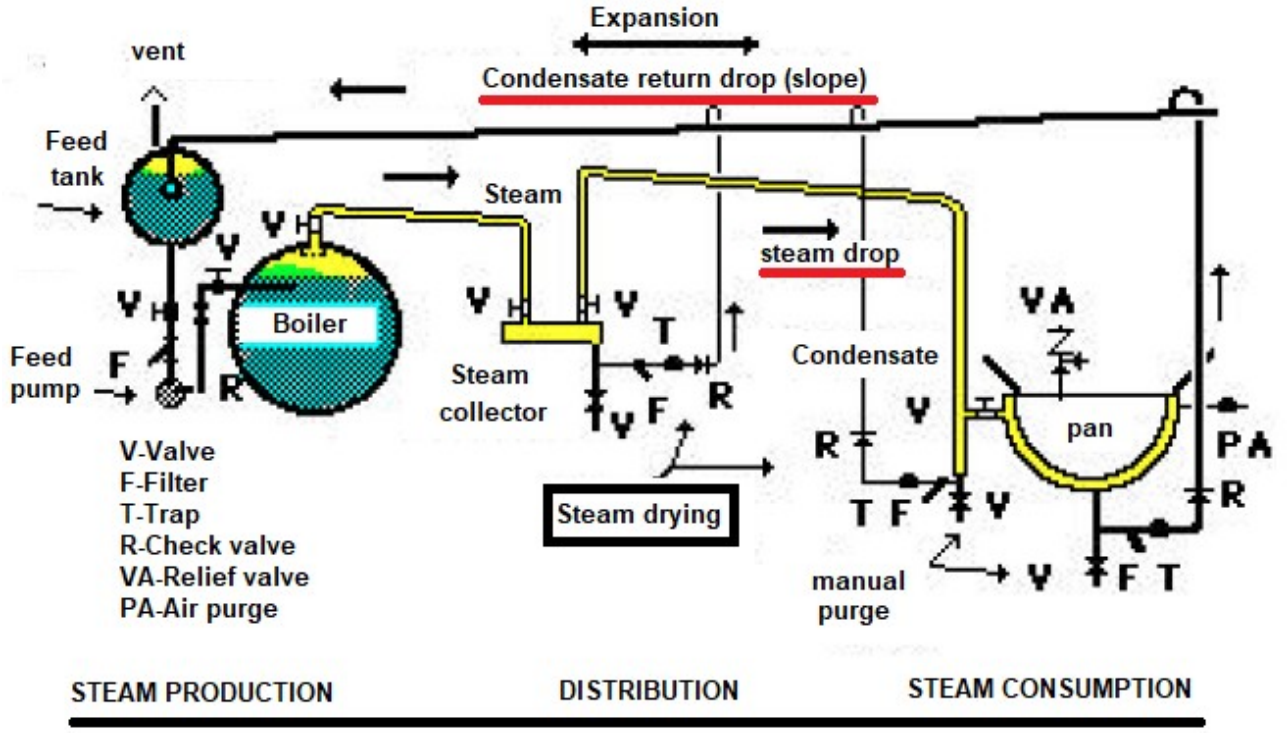
As we see in the previous table, the amount of heat Q is directly proportional to the temperature difference and inversely proportional to the thickness of the insulation and the K-value (a characteristic of each insulating material), and of course, also inversely proportional to its thickness.

There is a belief that "fiberglass" insulates better when it is "looser or lighter." This is a "myth," since what insulates is the "porosity" between the fibers.

Therefore, the smaller these pores, the less heat transfer occurs, as the air moves less; that is, the K-value increases with the density of the fiberglass.

The same applies, in a practical comparison, between a house made of concrete blocks and a house made of bricks (the latter insulates better).

The speed of the steam is between 15 m per second (54 km/h) in mild uses up to about 40 m per second (144 km/h) in uses where noise does not matter (there may be low pressure steams, i.e. close to absolute vacuum, which will be handled at more than 100 m per second, 360 km/h).



It is evident that the higher the steam velocity, the smaller the pipe diameter, but the greater the possibility of erosion, pressure loss, and noise that can be disruptive to people working nearby.

These velocities are what cause water hammer in the piping distribution.

Water has a significant density (weight per unit volume): 1 kg/dm³. If we imagine the mass of 1 liter of water (1 kg) at a speed of 100 km/h, stopped "instantly" against a metal wall, the energy it carries to reach that speed is released in fractions of a second, causing very large stresses.

Do not confuse "water hammer" with the knocking sounds produced by the "implosions" of the mixture of relatively cold water and "live steam" (in this case, "pops" are produced by the almost instantaneous condensation of the steam within the relatively colder water).To avoid "water hammer" and "pops" caused by water remaining in the lines, these should have a slope in the direction of steam flow (1 to 2%).

In each section that may condense due to cooling, a condensate removal system must be installed (manual drain with a "waste" bag, filter, steam trap, and retention or steam-condensate separators in areas where the steam is required to be "very dry," such as before regulating valves, steam atomizing burners, or in processes specifically designed for steam irons, etc.).

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A complete installation includes: manual purge drain with a "waste bag," filter, steam trap, and steam and condensate separators or retention tanks in areas where the steam is required to be "very dry," such as before regulating valves, steam atomizing burners, or in processes specifically designed for use such as steam irons, etc.

All steam outlets (or steam intakes for the steam consumption points of the industrial plant) must exit from the top of the pipes to avoid carrying over condensate water. This condensate, by gravity, circulates in the lower part of the pipe. The goal is for only dry steam to reach the consumption points, without any liquid water carried over from the condensate in the steam distribution line.

In some cases (pipes with a diameter greater than 3 inches), it is advisable to install a gas trap at the top of the line, and always at the bottom (regardless of the pipe diameter) a condensate purge to prevent the permanent accumulation of condensate (which causes corrosion and can contaminate the steam with oxides).

The condensate lines should also slope in the direction of flow, and the secondary pipes should enter from the top (to minimize condensate backflow towards the points of consumption, although 45° check valves are also advisable). They should also be insulated to prevent heat loss.

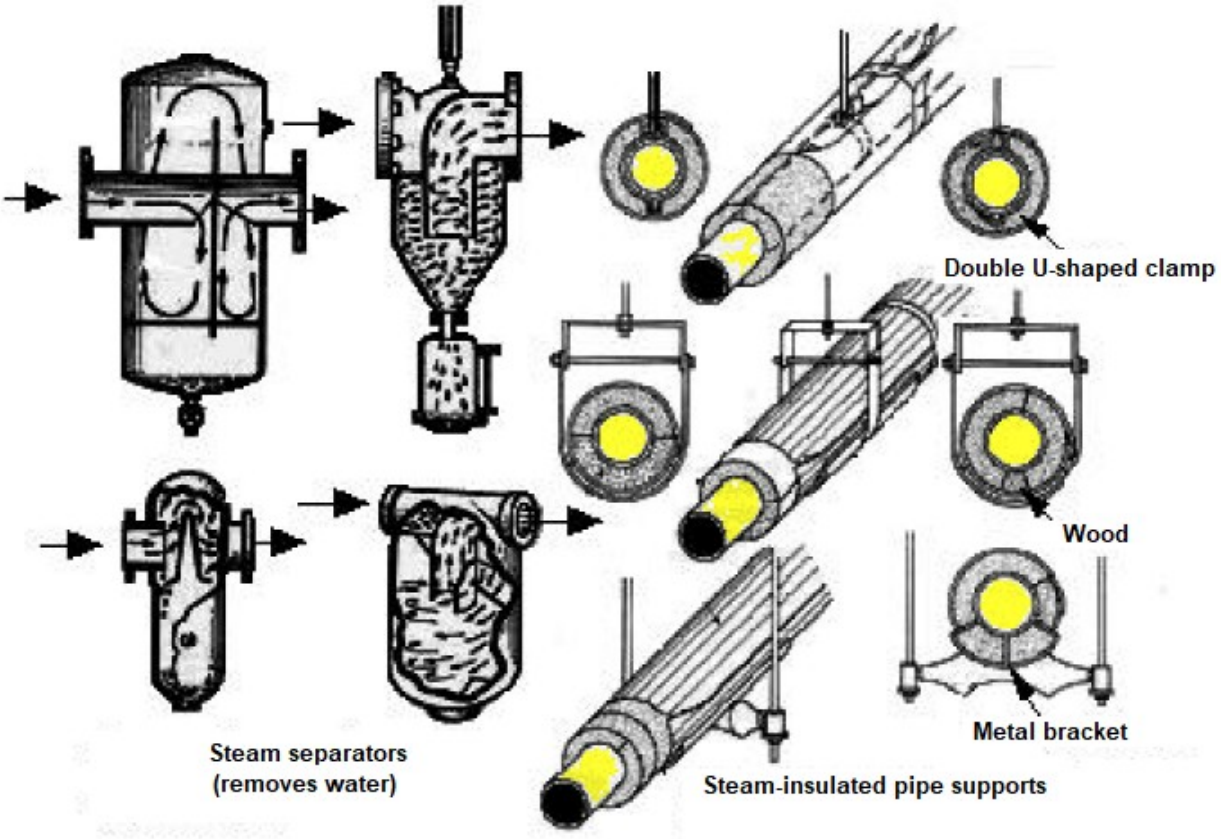
The gases produced by the decomposition of salts in the boiler's makeup water, as well as gases trapped within the boiler itself (due to contact with air or other gases, including condensate), are carried along with the steam produced in the boiler. These gases (which may be heavier or lighter than the steam) occupy space in the steam lines and heat exchangers, reducing their exchange capacity.

They cause corrosion and take up space that the steam needs to perform its heat exchange function. These gases must be removed to prevent these problems.

Heavy gases generally return along with the condensate (provided the traps are adequate for their removal) and must be extracted into the feed tank (venting) while maintaining the feedwater at a high temperature.

Light gases will not "fall" to exit the piping or heat exchanger, so they must be removed from the top using manual or automatic gas purges (thermal traps, thermodynamic traps, etc.).

A heat exchanger can lose more than 30% of its capacity if gas venting is inadequate.



ELEMENTS FOR STEAM DISTRIBUTION PIPES

Both steam and condensate pipes will expand (they lengthen when heated and contract back to their original size when cooled).

Therefore, we must study how to allow them to expand without creating stress or ruptures that could cause an accident.

If the pipes are not of a large diameter, they can be fitted with wide bends (avoiding elbows) in relatively short sections to allow for expansion without generating localized stress.

Otherwise, it will be necessary to install elements that absorb the expansion (expansion joints, Omega fittings, bellows, etc.).

Thermal expansion is approximately 1 mm per meter for every 100°C (212°F) increase in temperature. Therefore, only some of the pipes will be fixed, while others will be free to expand.

Care must be taken to ensure that the distances between supports do not create "sags" (downward curves due to the weight of the pipe). **These sags are low points in the pipe where condensate can accumulate and be carried away, causing a "water hammer" or "smacking" sound during commissioning.**

In any case, some supports will be fixed, while in others the pipe will be able to slide freely.

STEAM TRAPS

The use of steam for heating (steam as a heat source in industrial processes) can be done directly in some cases (heating water or water containing products that are not affected by the steam and its condensate).

Or indirectly: by preventing contact between the steam and water and the product being heated, and recovering the condensate.

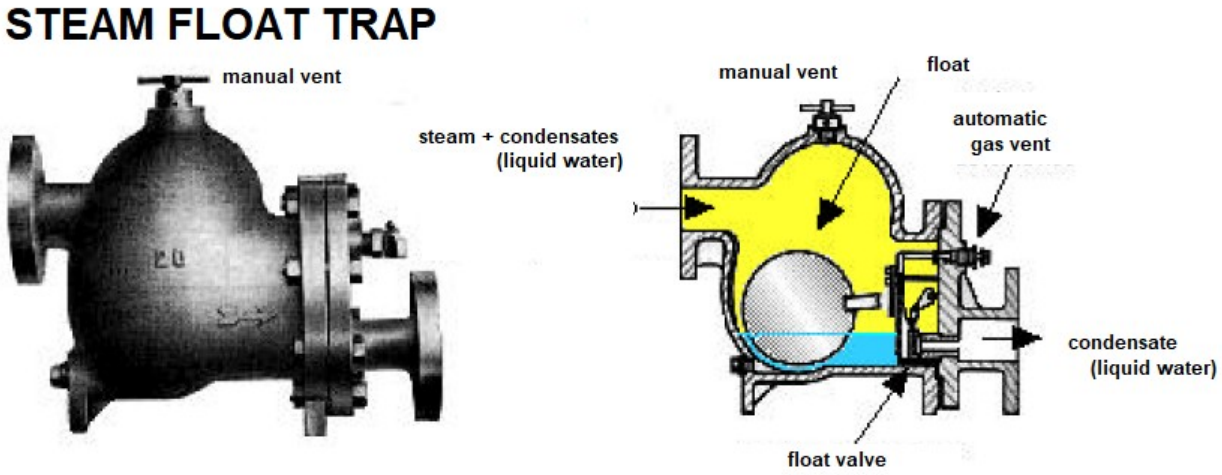
Condensate recovery plays a very important role in the quality of the feedwater: less makeup water, therefore less purge, better heat recovery, fewer chemicals, etc.

For indirect heating, we must ensure the efficient use of steam. Therefore, steam should not be allowed to escape from the heat exchanger until it has released its latent heat of vaporization, exiting the steam-consuming equipment as condensate.

For this purpose, we need steam traps.

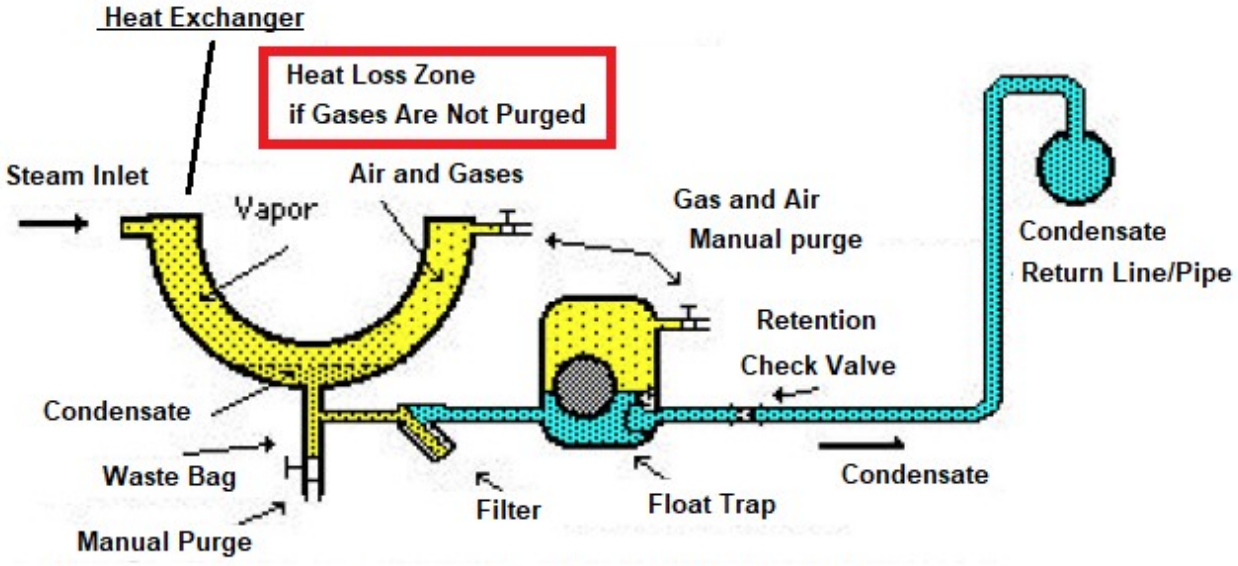
The function of the traps is to prevent steam from escaping and to drain the water that has condensed from the steam after it has released its heat.

The traps can operate in various ways or on several principles: the most basic would be the "float trap" (that is, a float or hollow sphere lighter than water and heavier than steam that rises as the water level rises and condenses. As it rises, it activates a valve that opens the outlet for this condensate, and once the condensate has escaped, as the level drops, the valve closes again).



This system needs an air or gas purge to prevent it from becoming "blocked" by trapped gases or air. This type of trap, the float trap, is ideal because it only allows the passage of condensate (whether superheated or not, i.e., above or below 100°C (212°F)), without consuming thermal energy to operate.

Other trap systems consume some form of energy to operate: normal bucket traps, inverted bucket traps, thermal traps, thermodynamic traps, etc., but they have other conditions that make them essential or desirable for certain uses.



Arrangement of Vapors, Gases, and Condensates in the Heat Exchanger

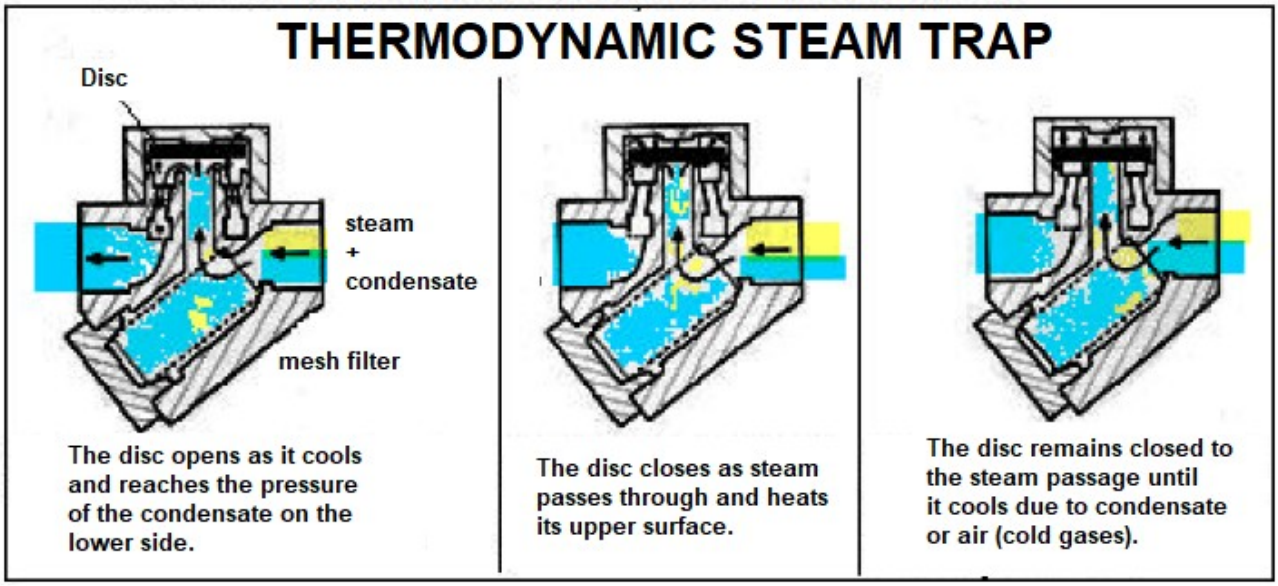
It is important to have the right steam trap for each use and condition; that is, each trap has a behavior that makes it better designed for certain applications or uses.

Large quantities of condensate, rapid or slower evacuations for subcooled condensate, high pressures, etc. And specific operating conditions (vapors contaminated with acids or alkalis, prevention of water hammer, superheated steam, etc.).

All steam traps must have a mesh filter at the inlet of the line steam, since condensate and steam carry hard materials from the pipes (metals, scale, etc.) that tend to scratch the valve seats of the traps, causing them to leak.

A leaking trap means that live steam can return through the condensate pipes without being used, and this loss can be quite significant in some cases.

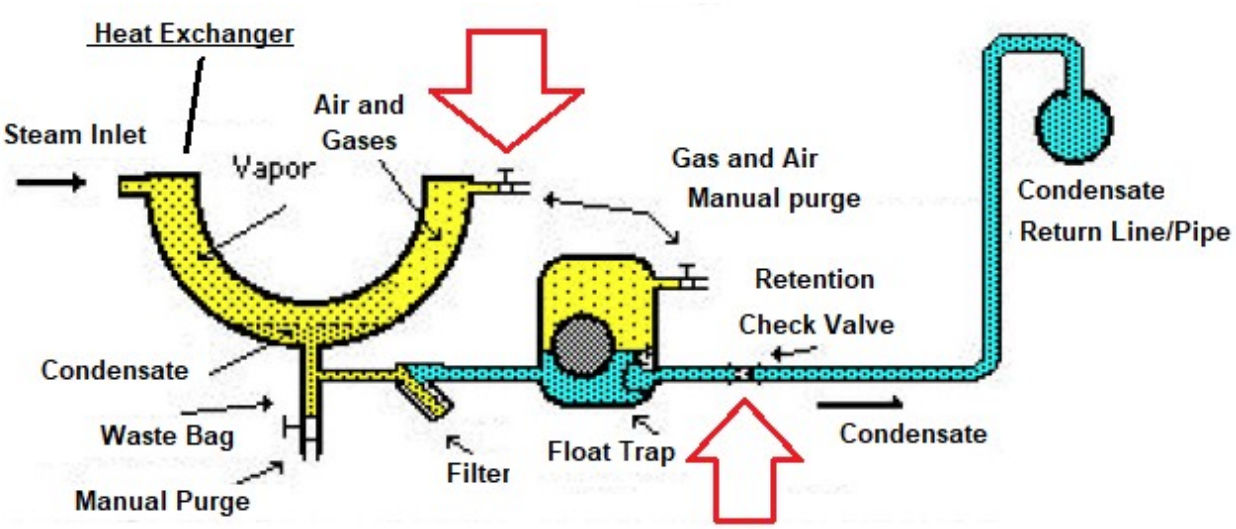
Some traps already have a filter built into their body, making an additional filter unnecessary. Pay attention to the metal used for the filter mesh; it must be stainless steel, otherwise it will corrode and become perforated quickly.


THERMODYNAMIC STEAM TRAP
Disc
steam
+
condensate
mesh filter
The disc opens as it cools and reaches the pressure of the condensate on the lower side.
The disc closes as steam passes through and heats its upper surface.
The disc remains closed to the steam passage until it cools due to condensate or air (cold gases).

It is good practice to install a manual drain valve before the steam trap, connecting it to a section of pipe that acts as a "waste trap." This means there should be a place where particles can settle and be periodically removed by gravity and the flow during draining, by purging the manual valve. The filters should be cleaned regularly.

Traps are not check valves, so in many cases it is advisable **to install a check valve to prevent condensate from flooding the heat exchanger** lines.

When shutting off the steam to the heat exchanger, be careful, as a partial vacuum may form inside. In some cases, this **vacuum must be broken by introducing air ("vacuum breaker") to prevent deformation** of the exchanger due to atmospheric pressure.



Whenever possible, prevent air from entering the condensate pipes, as the oxygen in the air accelerates the acidity of carbon dioxide (CO_2), leading to severe corrosion.

Some steam traps require condensate to be present inside them (bucket traps) to function. Therefore, we must be careful to use them in locations where condensate loss or backflow (from the trap itself) will not occur in the line and be replaced by steam or gases.

Choosing the right trap and designing the steam distribution and consumption system requires technical expertise that is often not found in textbooks.

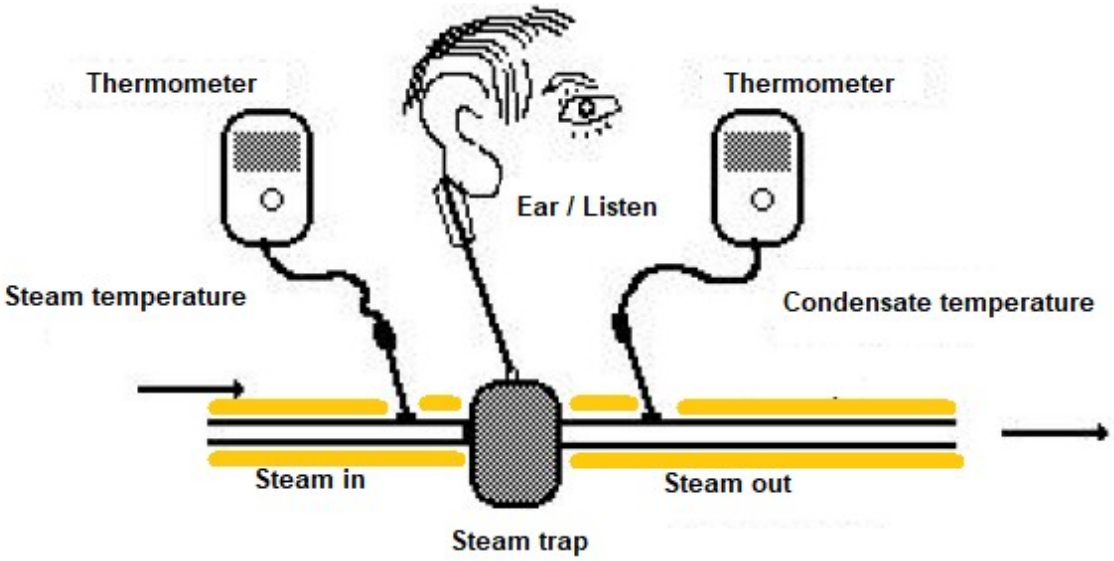
The installer must respect the slopes and bends in the pipes; these serve a purpose, they are not arbitrary or random, and are often key to proper operation.

Ensuring proper functioning and testing steam traps periodically is very important.

They can be tested by observing the steam circulating through an inspection window (which are not usually installed).

Or try using a screwdriver as a sound transmitter (or a mechanic's stethoscope). Depending on the type of trap, the noise can help us "suspect" it's malfunctioning. There are also "ultrasonic" devices that detect trap failures (i.e., the passage of live steam).

But a very interesting method is to measure the temperature on both sides of the trap. If the downstream temperature isn't significantly lower, it means live steam is passing through.



For example, if we're working at 10 kg/cm² (142 PSI), the temperature before the trap should be close to 180°C (356°F), and downstream of the trap it should drop about 40°C to 60°C (140°F), close to 100°C (212°F)).

All condensate discharged to a recovery system (feed or collection tank) must be at a higher pressure than the recovery system's pressure.

To achieve this, the steam temperature inside the heat exchanger (the steam consumption) must be at a value where the saturated steam pressure is higher than the pressure that must be overcome for discharge.

If the condensate temperature at the outlet to the recovery system is higher than the corresponding pressure of the recovery system, we say that we have superheated condensate.

Discharging at a lower pressure will cause evaporation until the temperature of the water and the resulting steam reaches the equilibrium temperature of saturated steam at the new recovery system pressure.

The fact that we have superheated condensate and that re-evaporation occurs after the traps (flash steam), if this re-evaporation is significant, will result in a substantial loss of heat that we will not be able to utilize. This must be studied to prevent it from happening.

Heat losses as FLASH STEAM

FLASH STEAM is produced because water leaves steam traps at the temperature of saturated steam or slightly lower (depending on the type of trap and installation or process), and when it comes into contact with a lower pressure, it re-evaporates (evaporates to the equilibrium pressure, taking heat from the superheated water, at the new saturation pressure, with the environment in which it is located, generally close to atmospheric pressure).

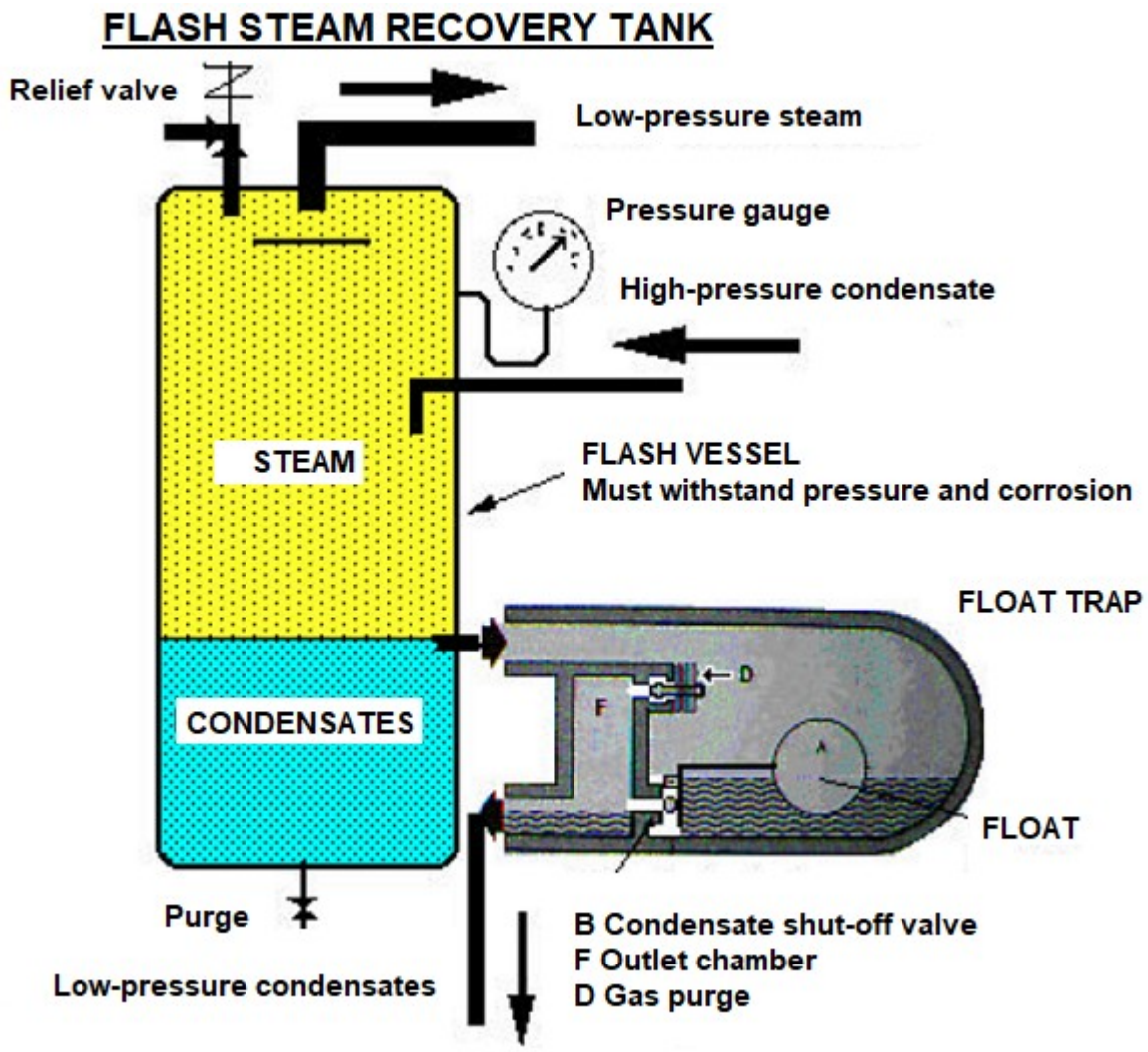
If this steam escapes into the atmosphere, it will be heat lost without being recovered, and with it, the water in the steam.

In other words, flash steam involves a double loss: the heat it carries and the water (condensed as steam, i.e., pure water).

Recovering FLASH STEAM can be as important as 15% or more of the energy produced.

There are several ways to prevent excessive flash steam production and various ways to reuse it in applications where the pressure (temperature) allows it.

Let's not forget that not only is energy lost, but also pure water (whenever possible, as much condensate as possible should be recovered).



In the previous figure, we have sketched a FLASH STEAM recovery tank.

Although there are other ways to utilize the heat from flash steam without using low-pressure steam, such as directly cooling the condensate and recovering the heat, or flashing the condensate under the boiler feedwater, utilizing the excess heat from the feedwater (in a water-to-water heat exchanger for plant use) or from water to air for heating in dryers.

The dimensions and the separation between the water and the steam are important (preventing entrainment with a separating diaphragm at the steam outlet).

Furthermore, it should be considered that the FLASH STEAM recovery tank, in the event of a system failure, can become pressurized to the boiler's operating pressure. **Therefore, it must have a good relief valve to limit its working pressure.**

It should also be considered that, due to the presence of condensate and corrosive gases, the construction material thickness must be sufficient to withstand corrosion and include a safety factor for overpressure (it is advisable to perform a hydraulic test at 1.5 times the high-pressure system).

The ideal trap is a float trap, leaving a water level inside the tank to maintain the internal equilibrium of the saturated steam. Thickness checks should then be performed in the lower section, especially during periods of fluctuating water levels, every few years of use.

Sometimes condensate recovery makes its use for boiler feedwater difficult due to cavitation of the feedwater pump caused by the high water temperature. The pump appears to have a "steam plug"; in reality, steam forms due to the high water temperature and the low suction pressure required.

This is corrected by positioning the feedwater tank at a sufficient height above the boiler feedwater pump (more than 4 to 5 meters above the pump) so that hydraulic pressure is generated, preventing re-evaporation (cavitation).

Some pumps are more prone to cavitation than others. These should be avoided, as draining the condensate and adding cold water is the worst possible solution in every sense.

The pump's suction piping is also important to prevent cavitation. A pipe with a small diameter, long length, elbows instead of bends, and a filter and valves with high pressure drop (generous filters and full-flow valves are needed) all contribute to pressure losses.

All of these factors add up to pressure losses that affect the pump's operation, causing cavitation due to the low suction required to overcome the pressure drop. This results in steam forming at the pump's suction.

Cavitation not only hinders water supply, but also causes pump failure due to mechanical corrosion, as the small bubbles collapse against the pump's metal, causing mechanical erosion that removes metal and promotes chemical attack, ultimately destroying the rotor diffusers (on the opposite side of the flow).

The height of the feed tank slightly affects condensate recovery by generating higher pressure at the discharge of the heat exchangers.

However, this is not usually a problem when operating at steam pressures above 1 kg/cm² (14 PSI). If this were to be an issue, it is preferable to install a low-pressure pump in a condensate recovery tank.

The tanks must be insulated and have bottom drains. **Never draw from the bottom of the tanks with the pumps to avoid pumping sediments (oxides, scale, sludge, etc.).**

The boiler's feedwater tanks must have adequate venting to release gases and air, which will be expelled when the tanks are heated by the return condensate.

If the condensate output is insufficient, it is advisable to install a heating pipe to heat the water to over 80°C, provided the tank's height above the pump allows it.

Homo-tubular boiler with 5 years of service, 365 days/year.
Classic internal chemical treatment, water softening.

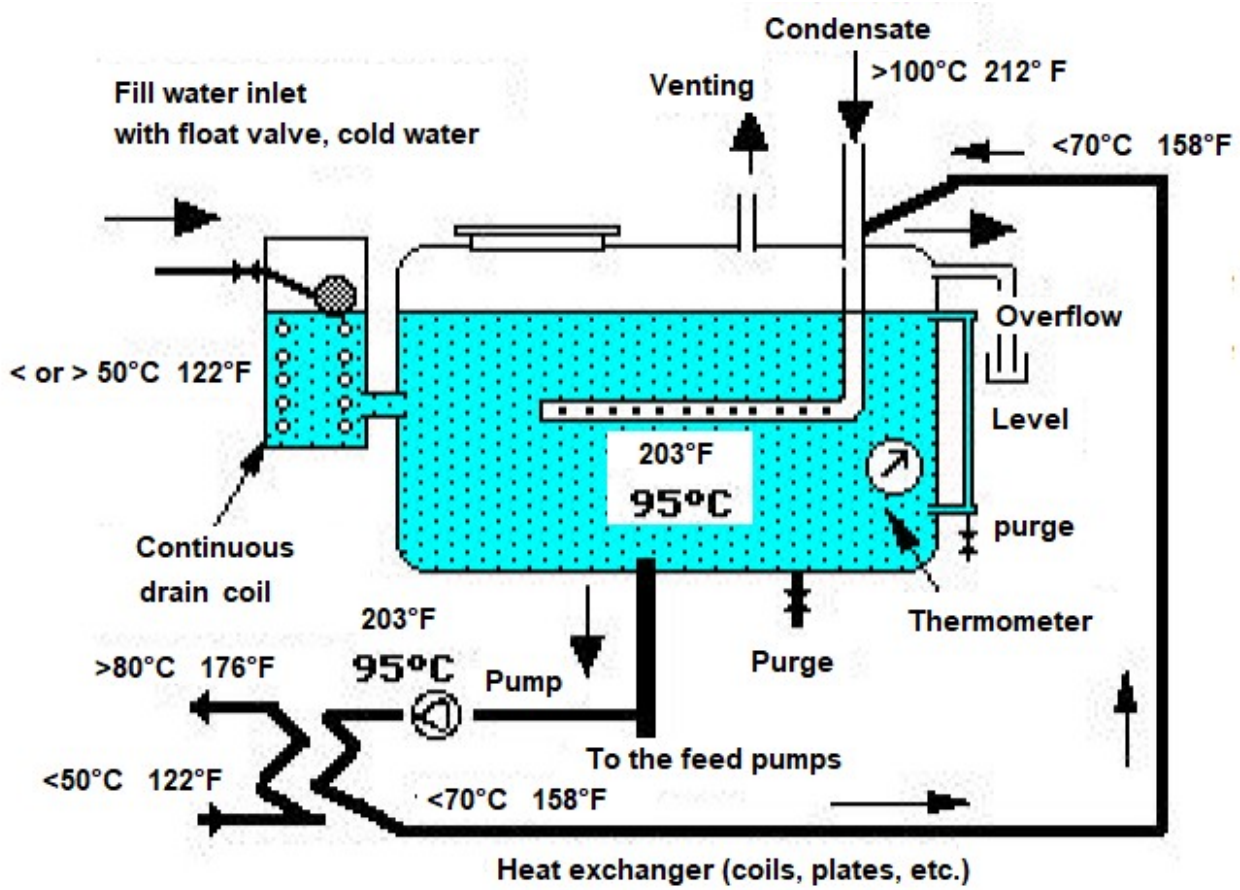
The following sketch shows a FEED TANK, incorporating some elements from our own experience (C.W.T. Carlos W. Thomasset experience):

1-Make-up water float outside the tank (to allow for repairs or maintenance while the system is running),

2-Continuous purge heat recovery coil in a cold zone (for greater heat recovery and to preheat the coldest water),

3-Condensate distributor under the feed water for flash steam recovery. Provided the tank water remains below 95°C (this requires cooling the feed water if it is overheated by the flash steam),

4-External heat exchange system for the feed tank water to utilize the excess heat from the flash steam (by heating water or air).



Feed pumps designed to operate at temperatures above 80°C (176°F) should ideally have **mechanical seals**, as **packing tends to overheat** due to friction and insufficient heat dissipation in very hot water. In this case, the pump packings should be externally cooled with cold water via a bronze ring through which the cold water circulates. This ring separates the packing into two sections, and its circular dimension is equal to that of a packing ring, providing internal circulation with water inlets and outlets.

(SOURCE: https://leakpack.com/difference-mechanical-seal-gland-packing/)

When operating equipment with "direct heating" (i.e., steam discharge directly into the water or water containing products to be heated: digesters, tanks, mixers, etc.**), it is advisable that the steam lines have a check valve, since shutting off the steam creates a partial vacuum that tends to draw in contaminated water**.

In the event of a power outage or accidental boiler shutdown (or steam shutoff), **contaminated water can travel through the steam lines to the boiler itself or, in combined systems with condensate recovery,** it can return as contaminated condensate produced by the "dirty" steam fed to the equipment when the steam system is restarted.

In the case of digesters, the situation is very serious, since they maintain internal pressure due to the temperature (balancing the feed pressure). When the boiler or system pressure decreases, they will tend to discharge through the steam supply pipe.

It is important that they have more than one check valve (of course, they must also have relief valves, regulated and limited steam pressure, etc.).

In all plants that are restarted, whenever they have been shut down for a period of time (more than a 6 or 8-hour shift), **it is advisable to drain the recovered condensate for a few minutes** to prevent potential contamination that could occur during shutdowns.

Therefore, it is necessary to install a valve that allows this recovered condensate to be drained before the condensate line reaches the feed tank.

Boiler water analyses generally indicate any contamination that may occur, allowing for measures to be taken, but it is more convenient to "prevent than cure" (to have elements and measures that avoid it).

Pressure regulators (devices that reduce steam pressure to a predetermined level) must operate free of condensate (their seats become scratched, and their calibrated orifices become perforated and clogged).

Therefore, it is necessary to install a **condensate separator with a condensate trap to dry the steam**.

It is also of paramount importance that they have **relief valves** capable of releasing all the overpressure generated in case the regulator valve ruptures when fully open (they generally tend to close).

If necessary, a **restriction (orifice plate)** should be installed with the valve **to limit the maximum steam** flow in case of rupture.

Choosing the right valve for each function and operating method: for example, **ball valves are excellent for quick closure, but should not be used to regulate flow** (the same applies to gate valves).

If flow regulation is required, a globe valve (or disc valve) should be installed, with a seat that allows for steam lamination.

Generally, in these cases, it is advisable to install two serial valves: **one for regulating**, connected to the steam utilization equipment, and **another for opening and closing**, connected to the steam supply, since the regulating valve will tend to leak steam as its seat deteriorates.

A well-planned and managed installation avoids many problems.